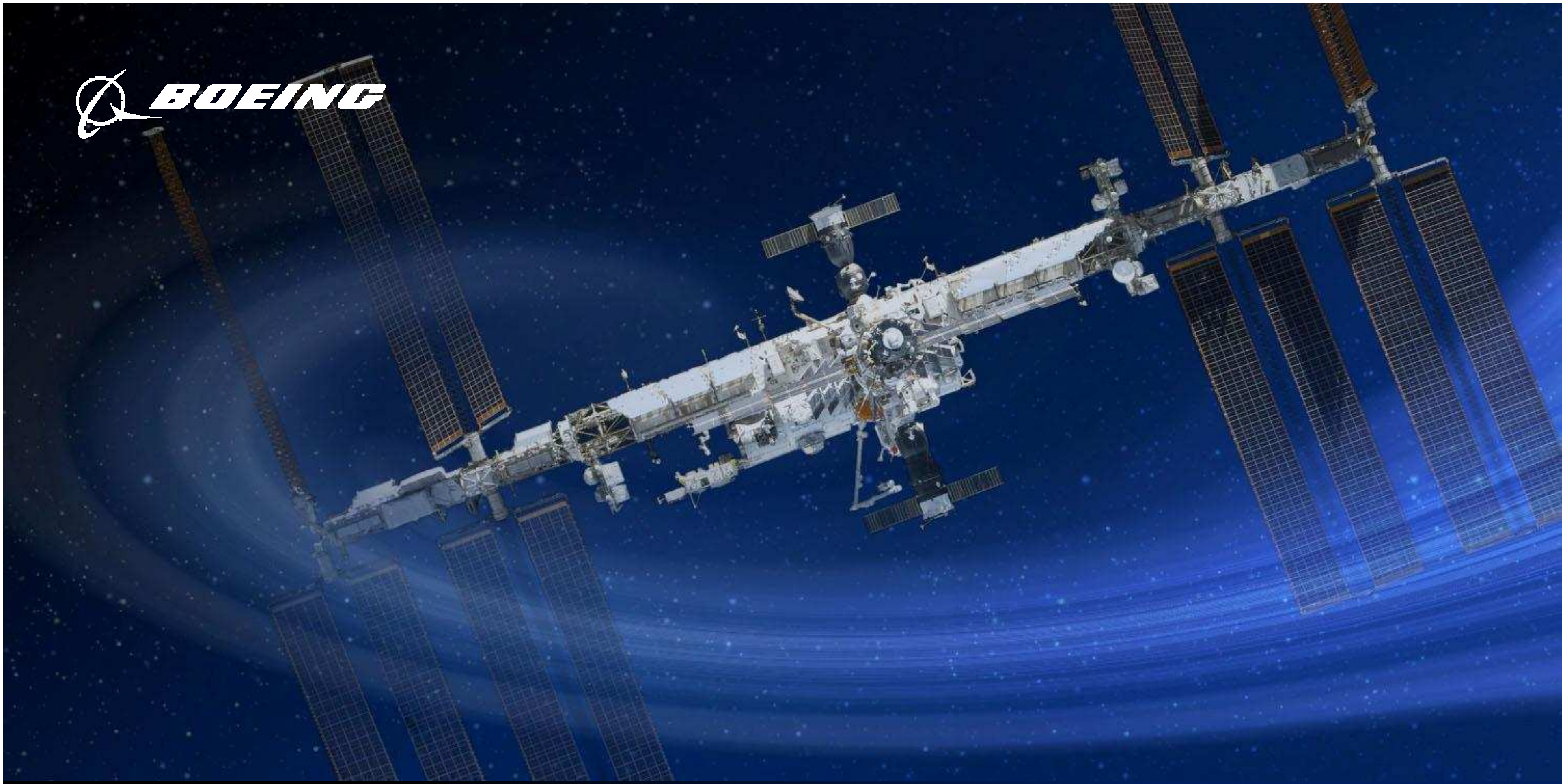
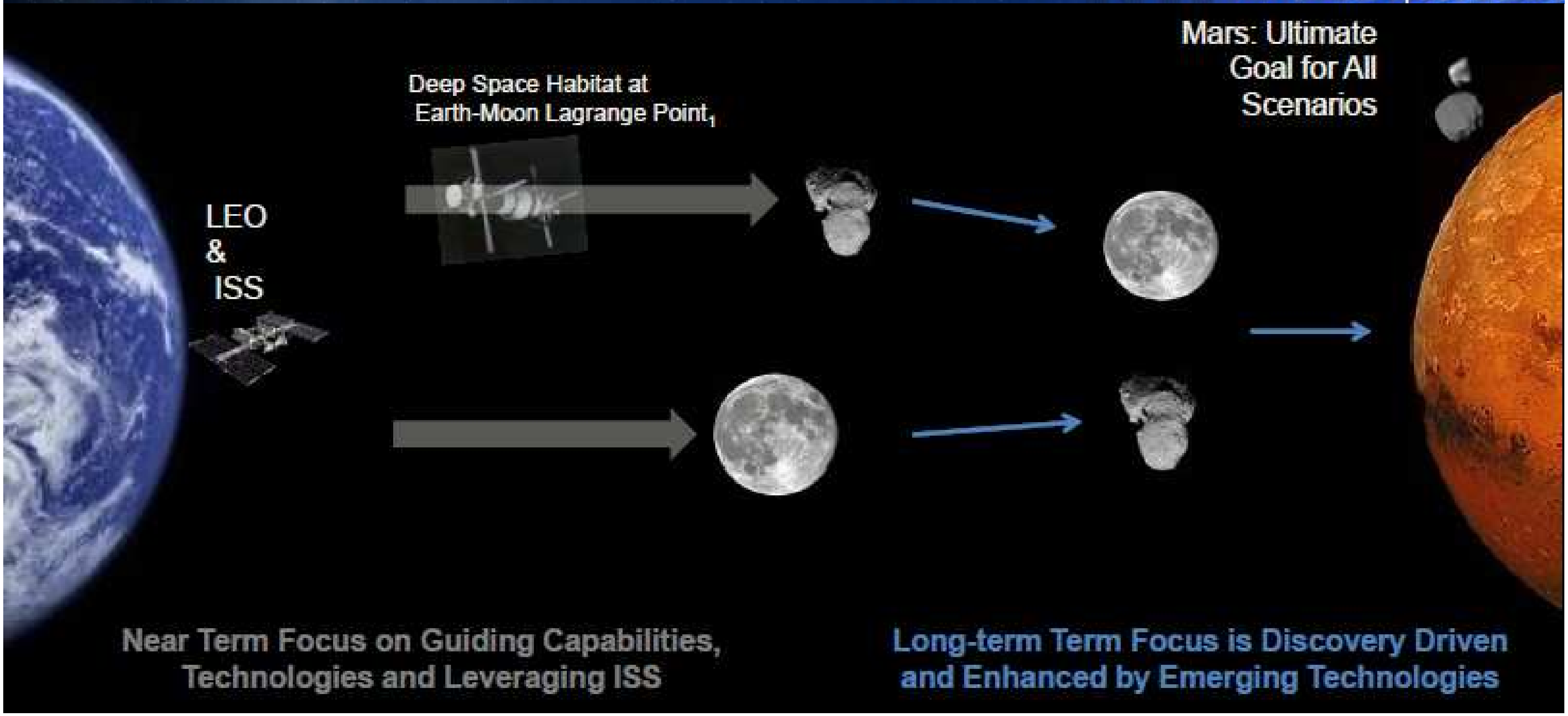


Global Exploration Workshop – Moon Mission Concept with Re-usable Lunar lander

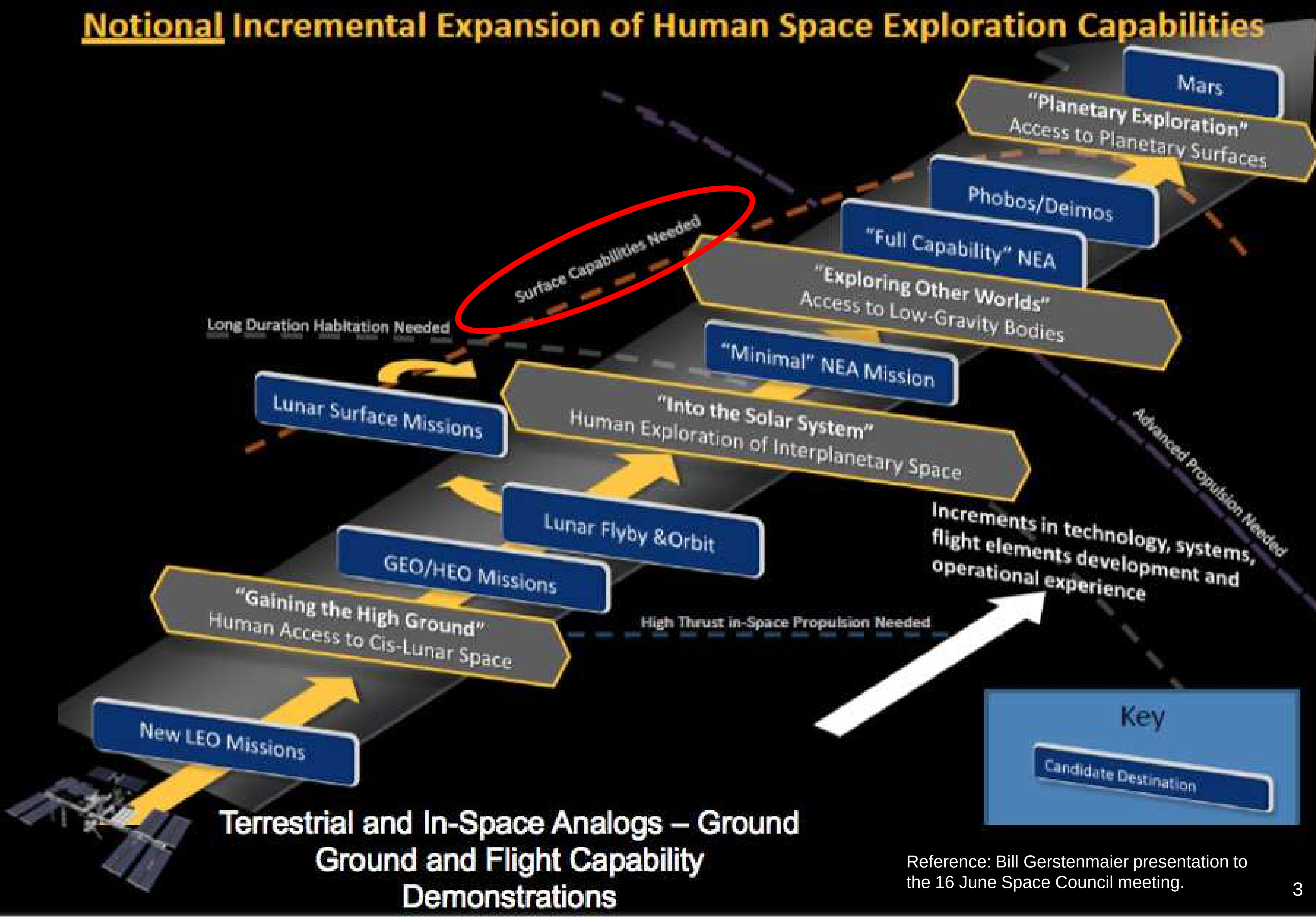
Ben Donahue
Sr. Principle Engineer, Phantom Works

November 15, 2011

Global Exploration Roadmap

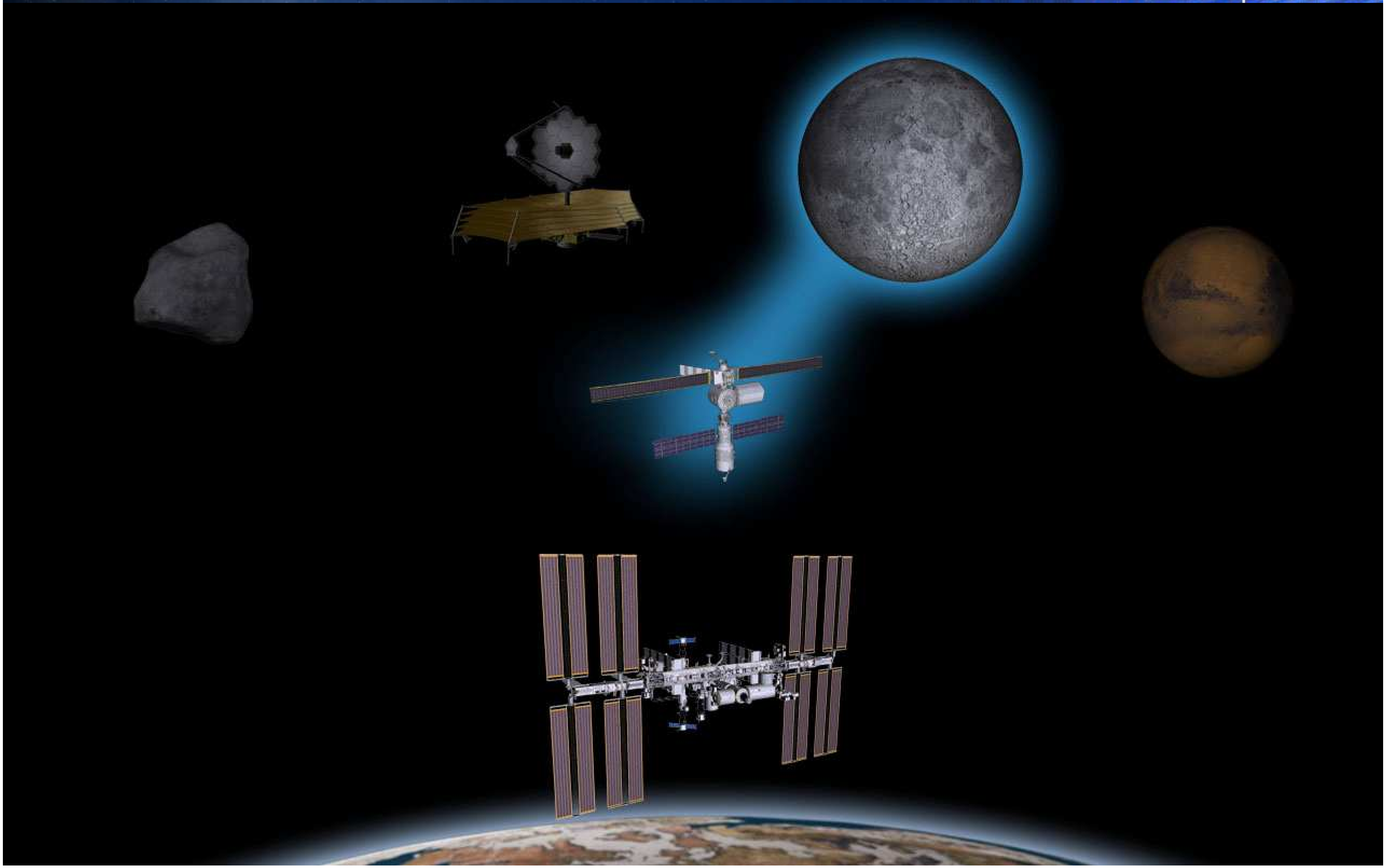


Capability Driven Exploration



Reference: Bill Gerstenmaier presentation to the 16 June Space Council meeting.

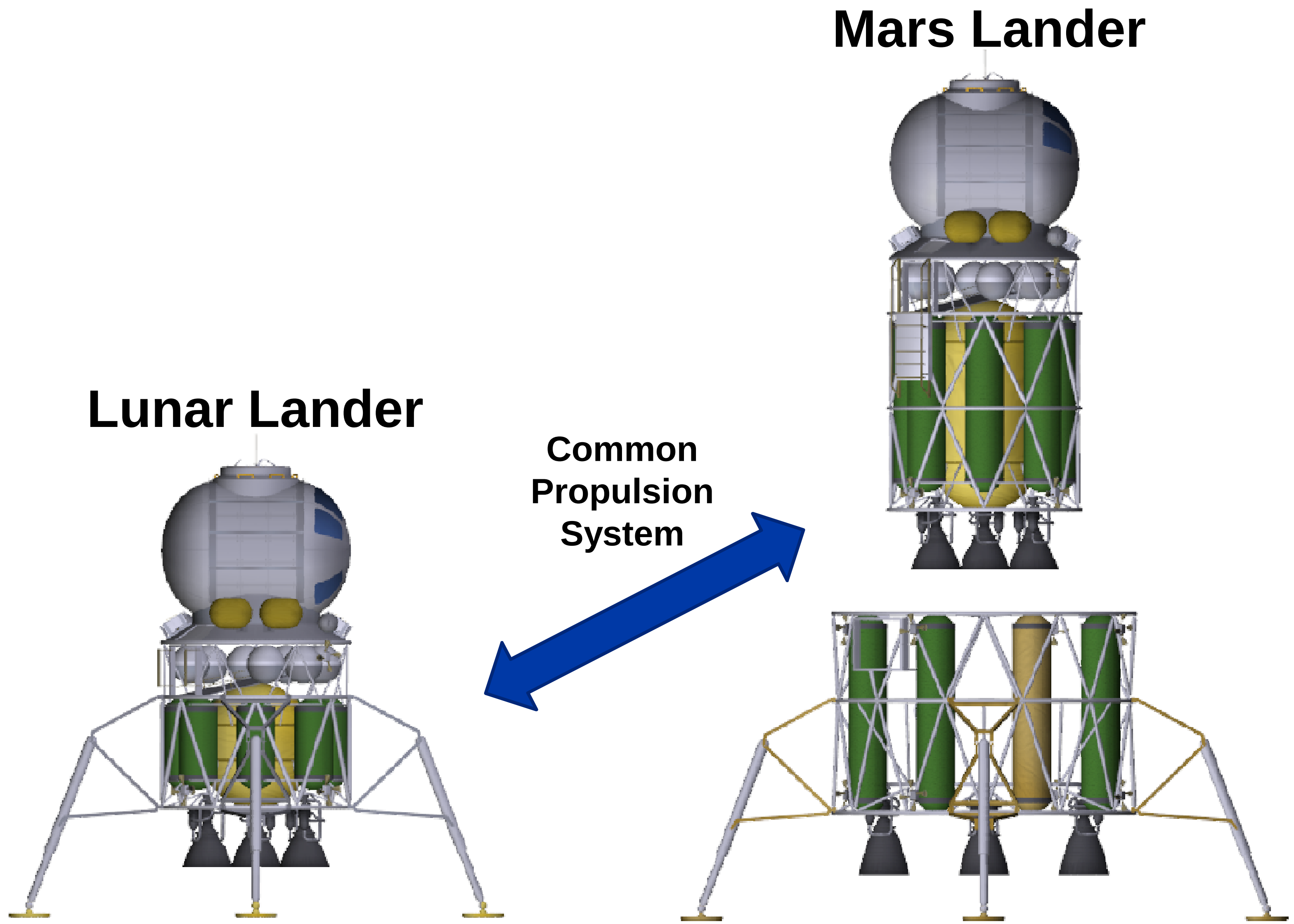
Flexible Path for Exploration



Re-usable Lunar Lander Based at EML1 / 2

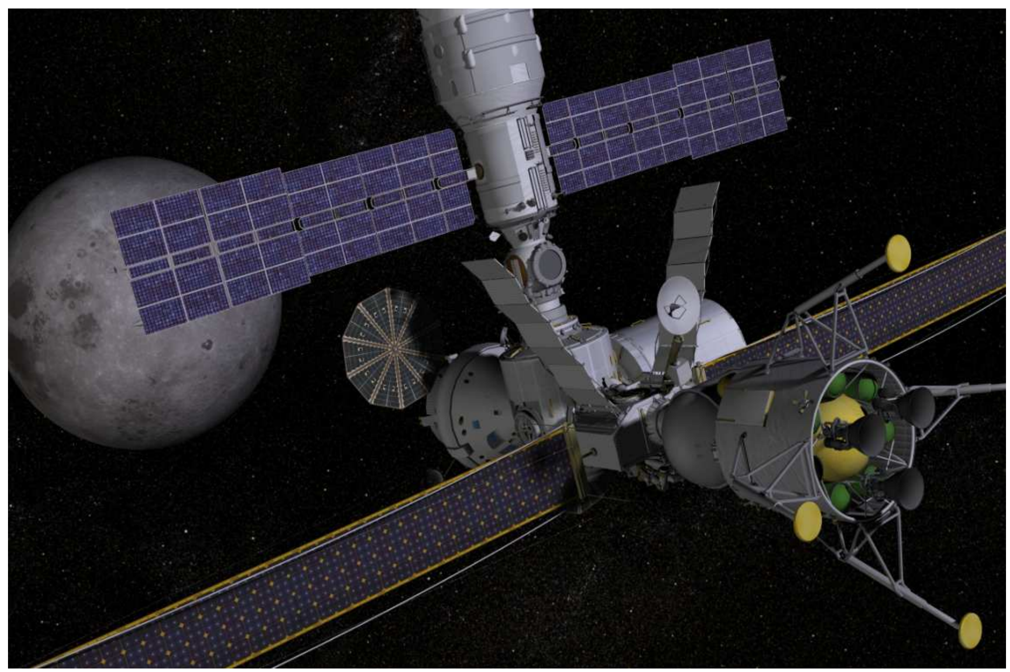
- **A Gateway at EML1 or EML2 allows re-usability of the lunar lander which saves money and enhances development of the ultra-reliable systems needed for Mars**
- **Our concept lander is much smaller than Altair; Dry mass of 7t, wet mass of 15t (Altair was ~45t wet)**
- **The propulsion system is designed to be re-fuelable LOX/Methane**

Lunar Lander as a Pathfinder for Mars



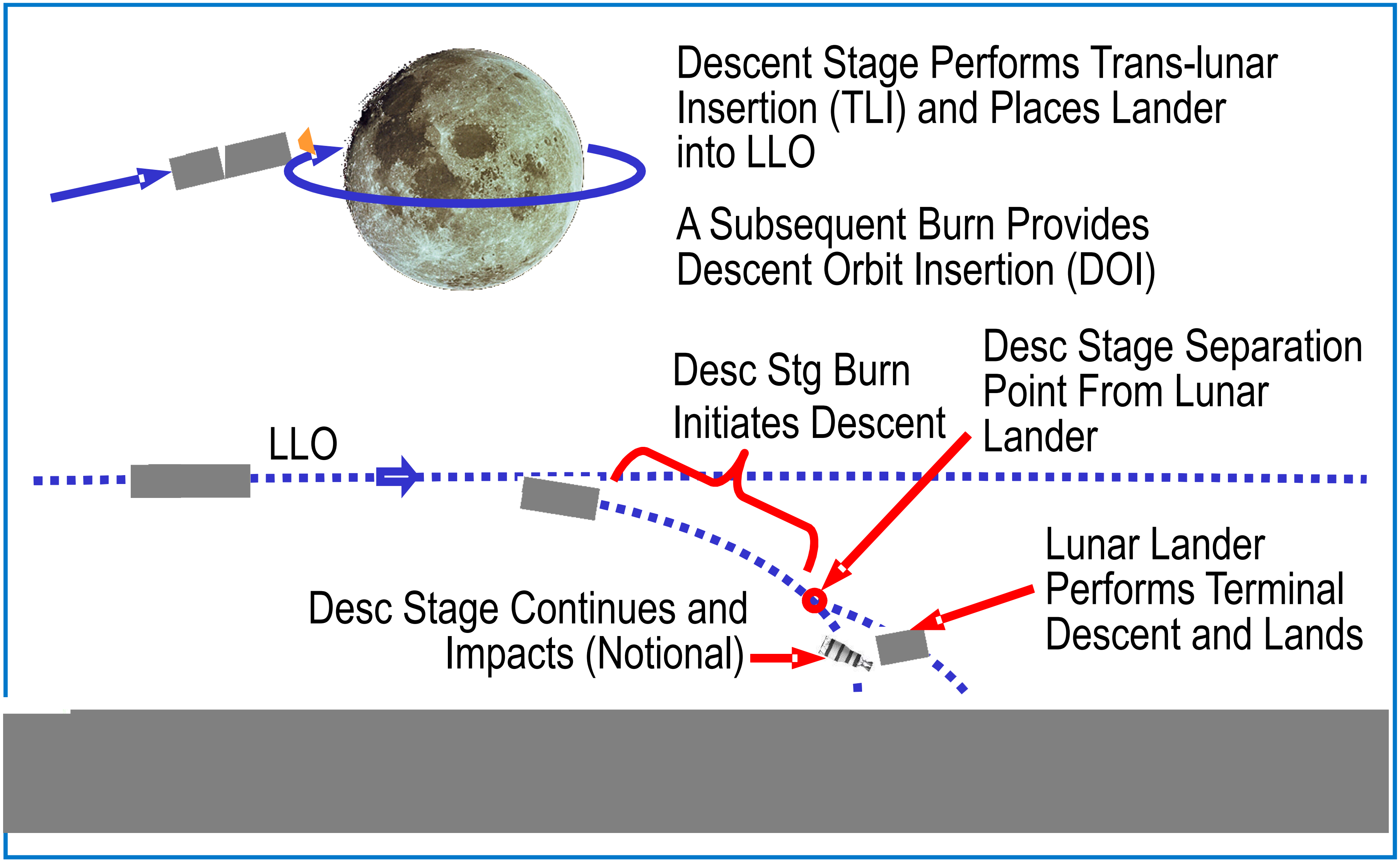
Delivery of the Lunar Lander to the ISS-EP

- **Commissioning crew flies with the lander to the platform**
- **Flight test program in the vicinity of the ISS-EP is used to prepare the lander for it's first landing**



Lunar Mission Flight Profile

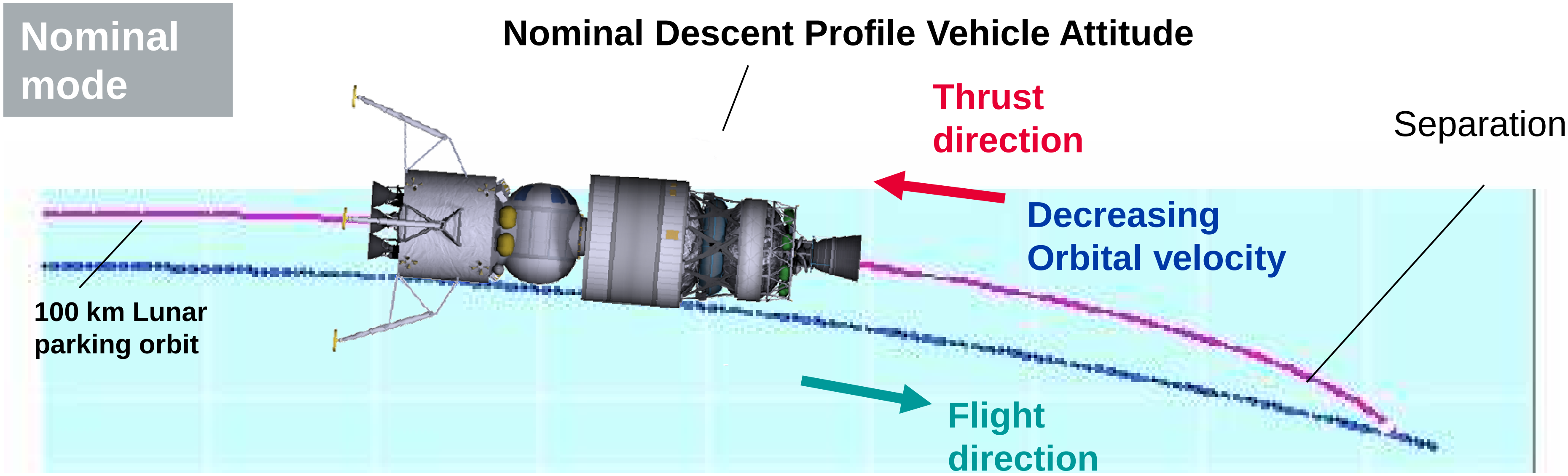
Defense, Space & Security
Space Exploration
International Space Station



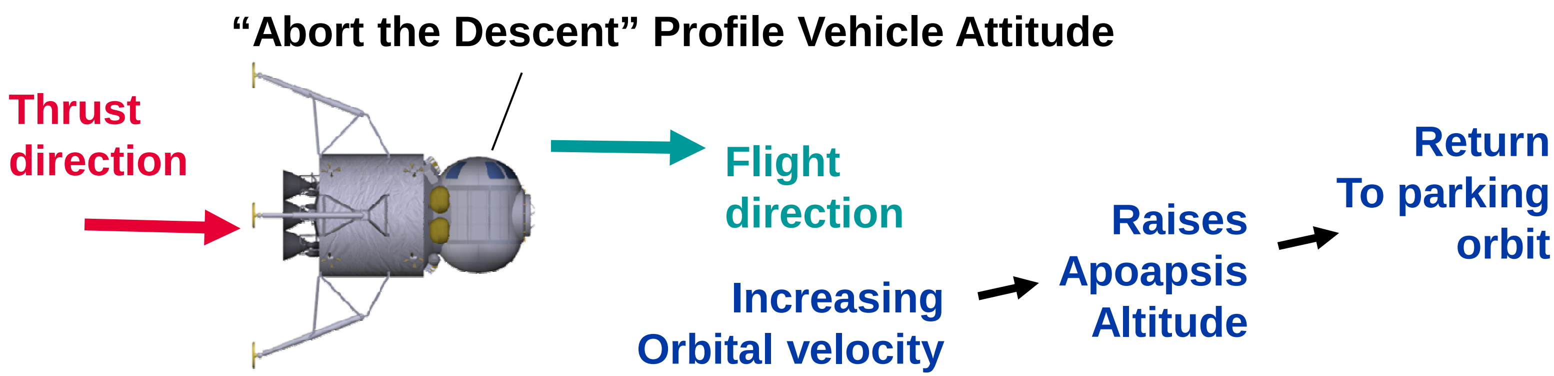
Lunar Mission Flight Profile

Defense, Space & Security
Space Exploration
International Space Station

Nominal mode



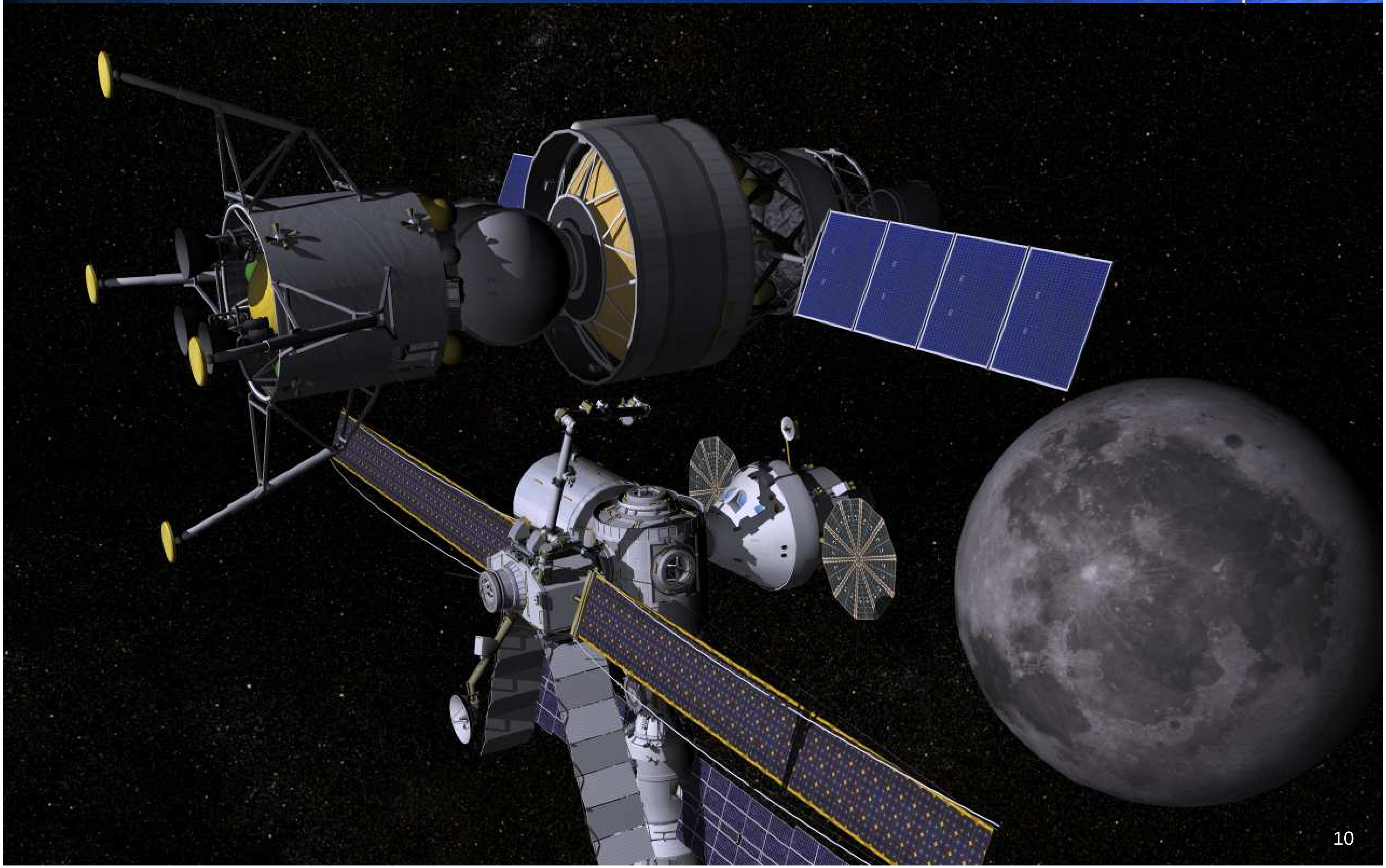
Abort mode



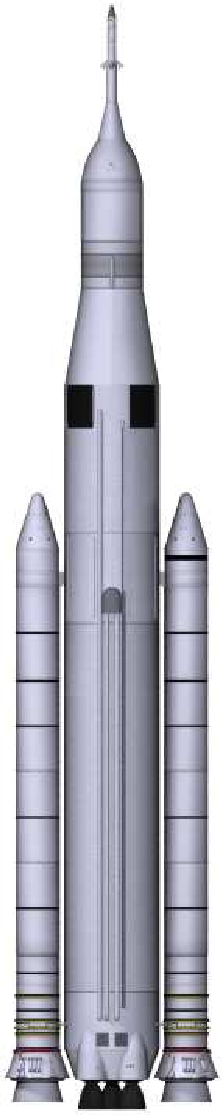
No Lander rotation required to initiate Abort to orbit burn

Lander is already in position to fire engines to return to orbit

Lunar Lander Departing the ISS-EP



Initial SLS Capability



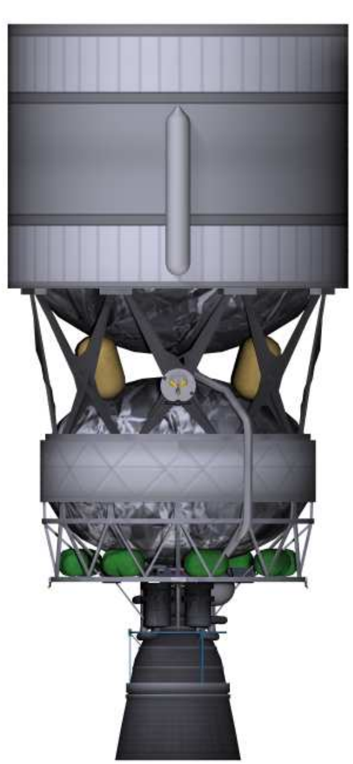
- **SLS provides the initial launch capability for exploration missions**
- **Lunar Mission Study Challenge:**
  - **Fly a complete lunar mission cycle with a single SLS launch**

Third Stage Evolution

Delta 5m Upper Stage

ARES 5.5m Tooling used to build demonstration tank

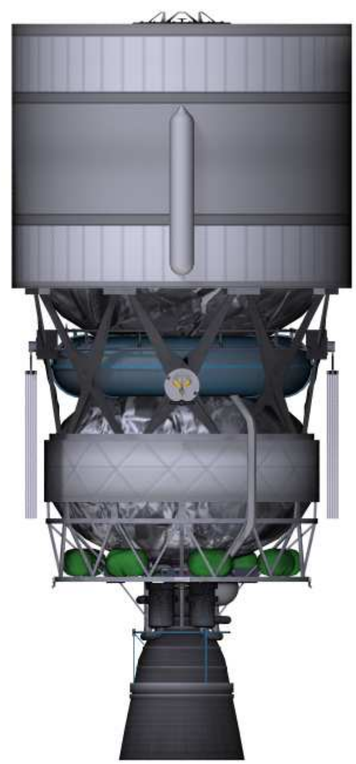
Block 1



- Tank increase from 5m to 5.5m
- 27t to 40t Capacity

Block 2a

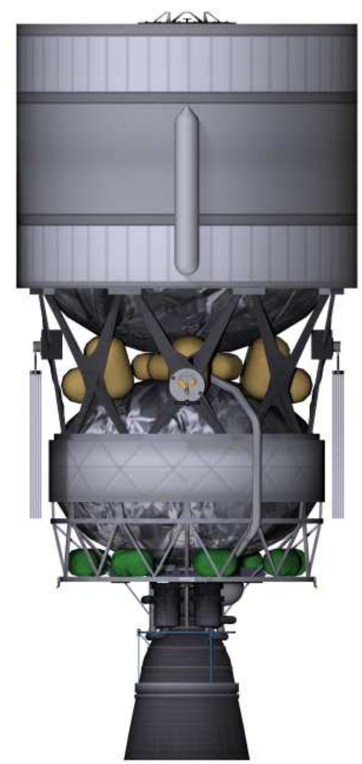
"Moon First"



- Block 2 NDS
- Orbit Kit
- Methane Tank

Block 2b

"NEA First"



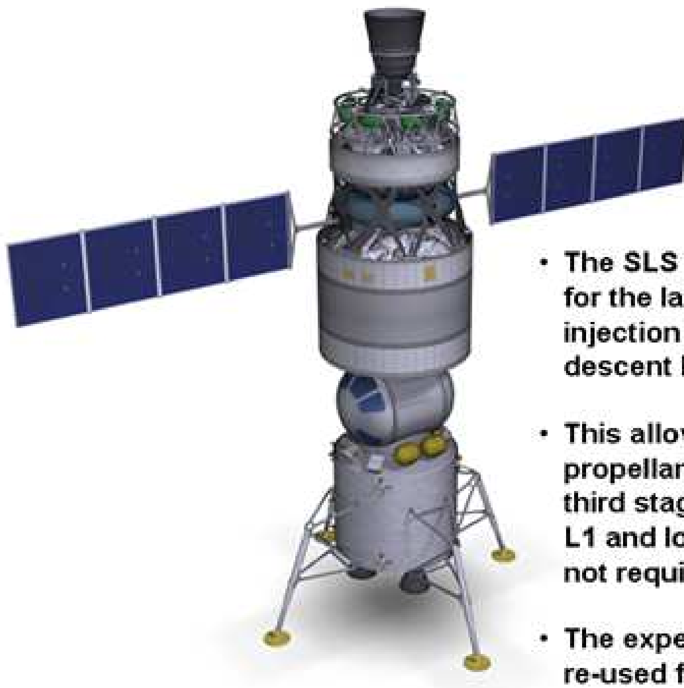
- Block 2 NDS
- Orbit Kit
- RL-10 Throttle

Block 2a Third Stage for SLS

- **Block 2a:**
  - “Moon First” Configuration
  - Adds solar array system
  - AR&D functionality
  - Enhanced RCS capability
  - NDS with fluid transfer capability
  - Additional tank (toroidal) for lunar lander methane delivery
  - **Assumes SLS 2nd stage will be completed**

Lunar Lander Recurring Operations

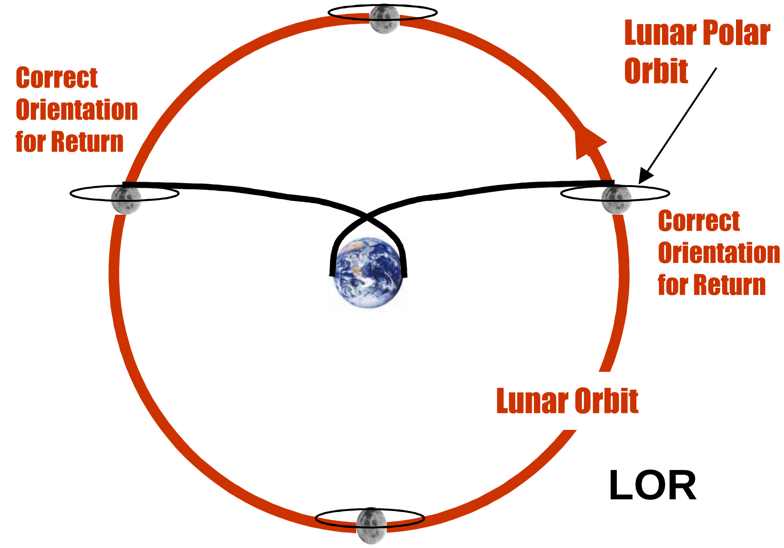
- **The goal for recurring operations should be to delivers the crew and all fuel for the lander in a single SLS launch**

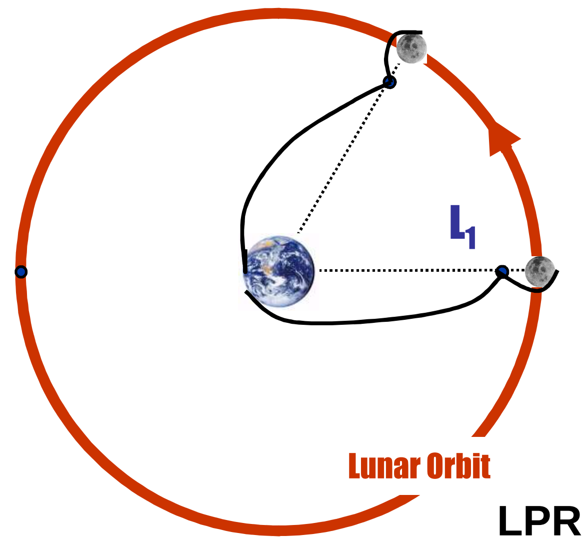


- The SLS third stage acts as the descent stage for the lander and performs the lunar orbit injection burn as well as most of the lunar descent burn
- This allows for the most efficient use of propellant because the high energy LOX/LH third stage is used immediately after it gets to L1 and long term storage of liquid hydrogen is not required
- The expensive crew cabin and ascent stage are re-used for multiple missions saving $$ Billions

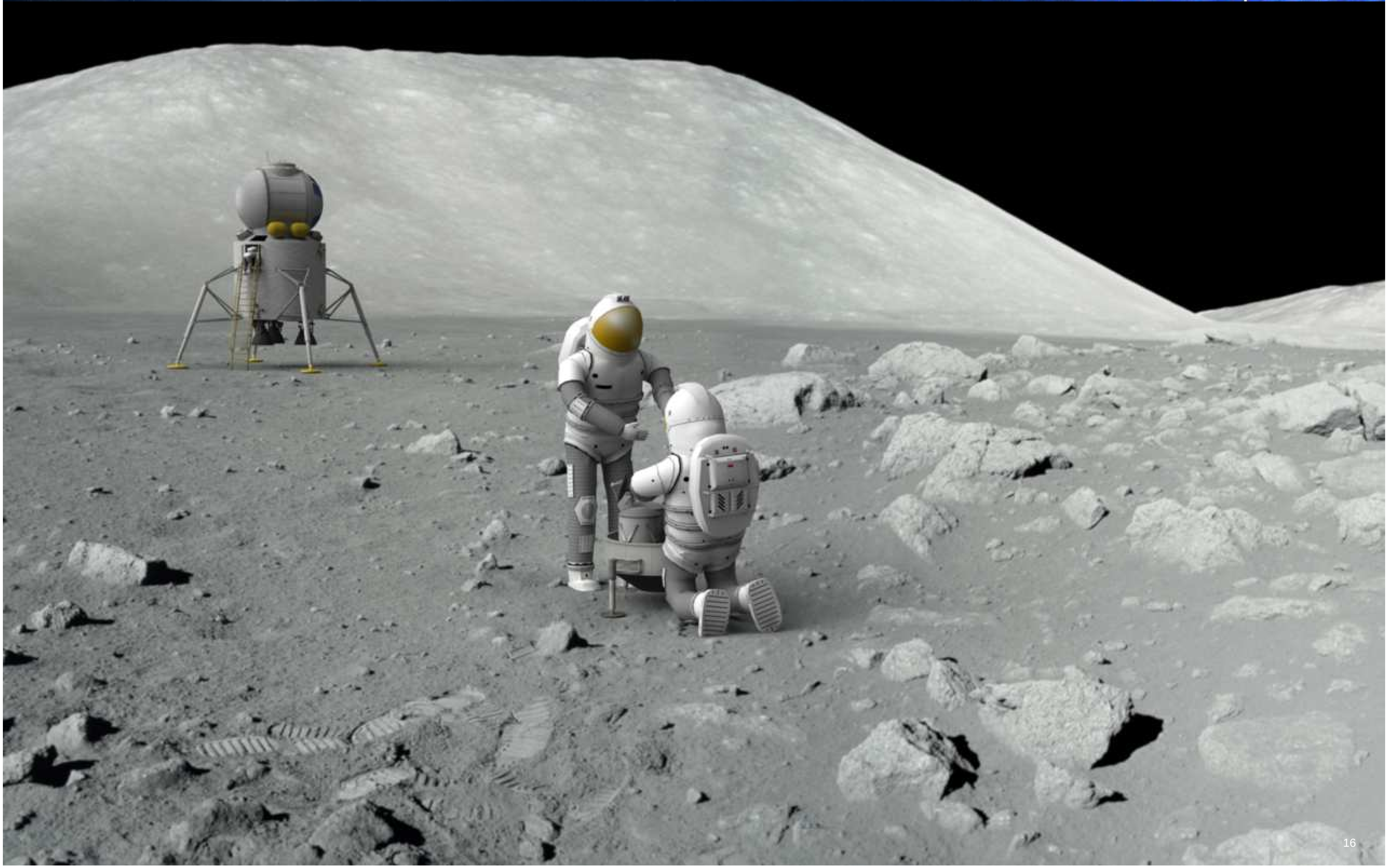
Lunar Site Access

- **Operational Considerations**
  - Lunar Orbit Rendezvous (LOR)
    - Access to lunar poles would require polar orbit if LOR mission mode utilized
    - Lunar polar orbit provides infrequent opportunities for trans-Earth injection (once every 14 days)
  - Orbit orientation inertially fixed, aligns with efficient trans-Earth trajectory twice a month
    - Total ΔV = 8951 m/s
  - Libration Point Rendezvous (LPR)
    - Continuous access from L_1 to lunar surface and return
  - Lunar rotation and libration point motion naturally synchronized
    - Continuous access to Earth - landing point partially controllable
    - Total ΔV = 10480 m/s
- **Unique science opportunities at L_1**
- **Deep-space human exploration analogs exist at L_1**
- **Support for deep-space human exploration missions**

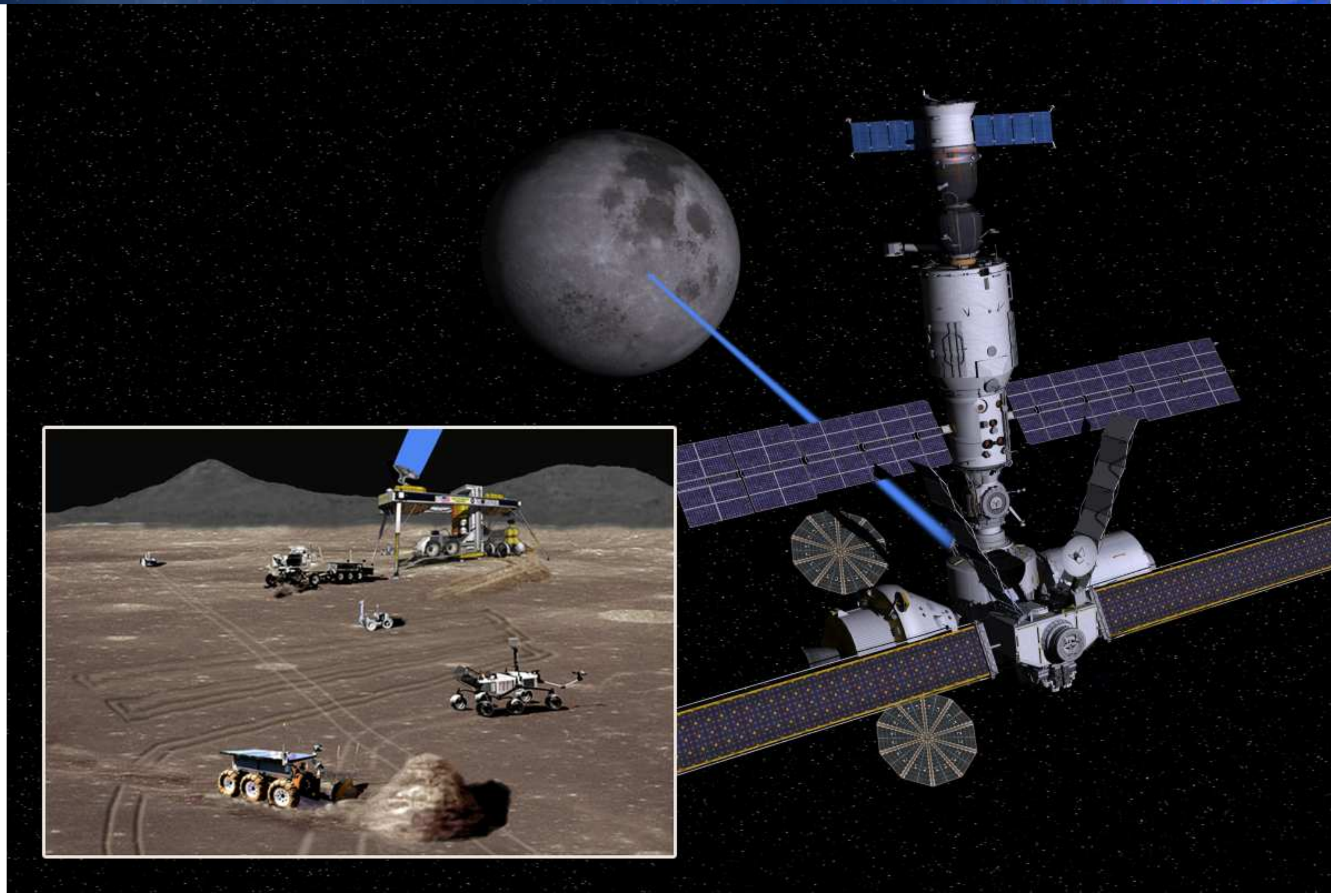




Lunar Lander on the Surface



Telepresence Precursor



On-orbit telerobotic control is a new way of viewing human-robot cooperation.

Dan Lester, Research Fellow
Department of Astronomy
dfl@astro.as.utexas.edu
University of Texas at Austin 512-471-3442

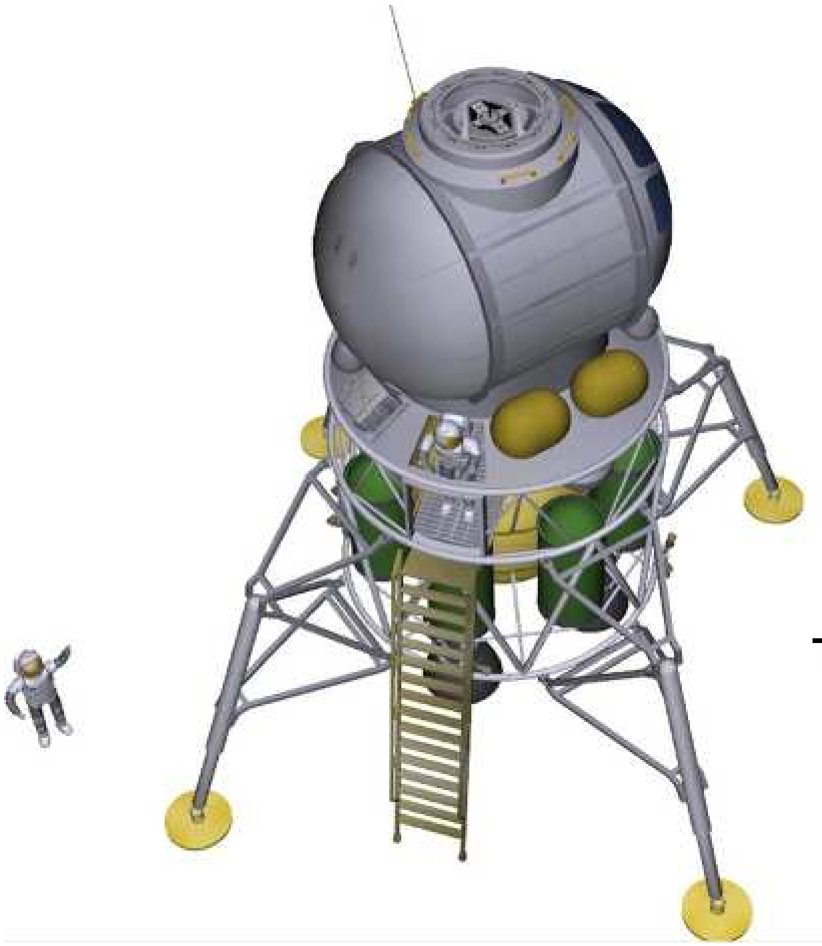
Lunar Mission – Summary

- Re-usable Lander – Pathfinder for Mars
- “Global Access” from EML1/2
- Telerobotics Precursor Potential

Backup Charts

Lunar Surface
Reusable Surface Hab and Crew Lander

Crew Lander –15 mt Total Mass



	mass	delta-V
Total Systems Mass	**14.98 mt**	
Surface Payloads	**0.50 mt**	
Total Lander Mass	**14.48 mt**	
Crew Cabin and Systems	**3.15 mt**	
Dry Mass	**2.72 mt**	
Propellant total	**8.61 mt**	
Propellant Masses	**8.61 mt**	**3,133 m/s**
Propel Reserves	**0.17 mt**	
L1 to LLO Prop Main	**n / a**	
L1 to LLO RCS	**0.02 mt**	**5 m/s**
Terminal Desc Propel Main	**1.92 mt**	**500 m/s**
Terminal Desc RCS	**0.04 mt**	**10 m/s**
Ascent Propel Main	**5.20 mt**	**1950 m/s**
Ascent RCS	**0.04 mt**	**10 m/s**
LLO to L1 Prop Main	**1.18 mt**	**640 m/s**
L1 RCS Prop	**0.04 mt**	**18 m/s**

Lunar Mission Mass Estimates

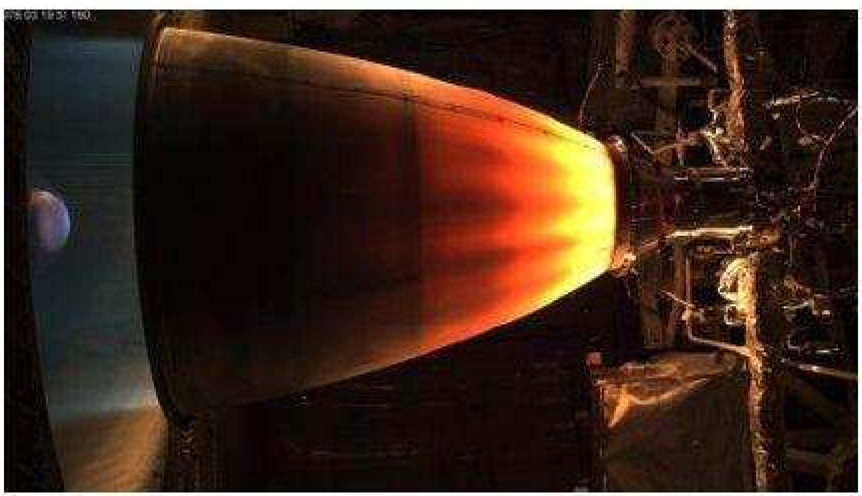
Table 4. Lunar Crew Sortie Mission Mass (mt)

	Location	Mass	2ND Stg	3RD Stg	MPCV	L1 Payl	Lander	adapt	Comment	prop used
1	Asc L1 (2Stg)	209.6	138.3	45.0	16.7	6.7	n/a	2.9	2Stg burn1	121.6
2	Asc L1 (3Stg)	69.0	n/a	45.0	16.7	6.7	n/a	0.6	3Stg burn1	24.9
3	EML1	44.1	n/a	20.4	16.7	6.7	n/a	0.6	arrive L1	n/a
4	EML1	44.1	n/a	20.1	16.7	6.7	n/a	0.6	3Stg connect	n/a
5	Sep from L1	35.6	n/a	20.1	n/a	n/a	14.9	0.6	add lander	n/a
6	Depart L1	35.6	n/a	20.1	n/a	n/a	14.9	0.6	3Stg burn2	5.0
7	LLO	30.6	n/a	15.1	n/a	n/a	14.9	0.6	arrive LLO	n/a
7	LLO-desc	30.6	n/a	15.1	n/a	n/a	14.9	0.6	3Stg burn3	9.5
8	desc	21.1	n/a	5.6	n/a	n/a	14.9	0.6	3Stg jettison	n/a
9	Desc lander	14.9	n/a	n/a	n/a	n/a	14.9	n/a	lander desc	2.0
10	On L Surf	12.9	n/a	n/a	n/a	n/a	12.9*	n/a	lander asc	5.3
11	LLO	7.5	n/a	n/a	n/a	n/a	7.5	n/a	lander to L1	1.2
12	EML1	6.3	n/a	n/a	n/a	n/a	6.3	n/a	arrive L1	n/a
13	Depart L1	16.7	n/a	n/a	16.7	n/a	n/a	n/a	MPCV sep from L1	

* 0.5mt Surface payload drop

LO2 / Methane CH4 Engines for Descent and Ascent

ISRU derived Methane may be used for Mars ascent descent
Developmental programs underway at Aerojet and ATK/COR
LO2 residuals left in desc stg tanks available Crew on surface
Pump-fed Methane engine provides significant Isp (372 sec) over press-fed storable engine (320-328)
Shared propel tank O2/CH4 main / RCS system in test



Aerojet, T = 5.5 k-lbf, Isp = 350 sec

ATK/XCOR, T =7.5 k-lbf

Lander Close Up View